MOOR HOUSE

15th Annual Report, 1974

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THE NATURE CONSERVANCY COUNCIL

MOOR HOUSE

1974

15th Annual Progress Report

M. Rawes

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I. GENERAL

a) Introduction

This Report covers the year 1 October, 1973 to 30 September, 1974.

The Nature Conservancy Council, which was established in November 1973, is an independent statutory body funded by Grant in aid administered by the Department of the Environment. Among its functions, it now undertakes the conservation work of the former Nature Conservancy, and has, therefore, inherited the National Nature Reserves established by that body, including Moor House. The emphasis always given at Moor House to research and education as the basis for conservation is fully in line with Reserve policy announced by the new Council.

At Moor House we are engaged in managing a Reserve, which has a 22 year history of research, maintaining a Field Station for visiting research workers, and continuing a programme of survey. Giving of advice and carrying out surveys are not, however, confined to the Reserve, but include other places and habitats, usually within the county of Cumbria.

It is pleasing to note that original research and survey findings from Moor House continue to be used and quoted in a variety of ways. In the recent New Naturalist publication "The Lake District" by W.H. Pearsall and W. Pennington, the chapter on Climate utilises Moor House and Great Dun Fell data. Likewise publications of the International Biological Programme projects have used much Moor House information to support and compare results. Dr. O.W. Heal contributes an account of the affairs of the Programme in this Report.

In the last month of the reporting year the Reserve was declared in Washington as the world's first Biosphere Reserve in the United Kingdom. It thus becomes a special area in UNESCO's Man and Biosphere Programme, Project No. 8, "Conservation of Natural Areas and the Genetic Resources they contain".

The primary objectives of Biosphere Reserves are:-

1. To conserve for present and future use, plants and animals in natural ecosystems, and safeguard the genetic diversity of species.

2. To provide areas for ecological and environmental research.

3. To provide facilities for education and training.

The long history of sheep grazing has modified the vegetation of the Reserve but many features of a natural system exist. Research and education have always been encouraged. The existing laboratory facilities and hostel accommodation with research areas nearby enable visiting scientists to make the best use of their time.

b) Reserve Management

Maintaining and improving the scientific and conservation values of the Reserve are the main functions of management. The scientific interest has been much enhanced by the previous heavy investment of research capital. There is every expectation that this investment will continue and be utilised in practical conservation management. The safeguarding, especially of existing research sites, some of which are fenced, becomes more important each year. For over 20 years some sites have been kept free of sheep grazing, and, as such, provide useful data on vegetation change and management. The maintenance of fences, often on exposed sites, presents many problems and numerous repair and replacement assignments have been necessary. We now find ourselves with a major task of renewal, and, within the next 5 years, plan to replace all enclosures to give each a further 20 years life. Materials are being assembled for this.

Lack of natural predation and the recent relatively mild winters have been responsible for an unprecedented rise in the rabbit population so that control measures to protect trees and enclosed vegetation have become necessary. Rabbits are widespread throughout the Reserve, up to an altitude of 2500 ft (766 m), especially where limestone outcrops. Another problem has been the browsing of trees by roe deer. There is little doubt that the tree enclosures are proving an attraction to wildlife.

Regular burning each year of a small part of the heather moor has been customary practice. Since 1960, burning has been confined to the eastern part of the Reserve, but this year it was decided to link the burning more closely to the annual survey of grouse numbers, so fires were confined to the two 200 acre (81 ha) study areas. Burning, rarely easy in this environment, took place during the last days of March, when some 31 small burns accounted for 5 acres. The state of the heather itself has been very poor due to the dry but cold snow-free conditions in March and April. Furthermore new growth was killed, or received a severe check, during the exceptionally cold night of 27 June. Trees and most vegetation were adversely affected by this frost. The hay crop was one of the lowest on record, but in a generally poor hay year, the crop was harvested in good condition. A small plot of turnips, which have grown well and attracted public interest, were direct sown to provide additional winter feed for the sheep. In the spring a small number of trees were planted in existing fenced areas near the house. The species included lodgepole pine and sitka spruce and locally gathered self-sown birch, willow, and rowan.

The heaviest public pressure continues to be on the west side of the Reserve, where the road provides easy access to the top of the Pennines. Mr. J. Rose, part-time Warden, continued to supervise the ski-ing on Great Dun Fell, although lack of snow, for the third successive year, resulted in fewer skiers coming than for many years. Mr. B. McArthur, honorary Warden, undertook the duties in March. Use of the Pennine Way increases and erosion of the track has made it necessary to adopt some remedial action. Firstly, the track has been marked by posts and signs, which the majority of walkers have accepted and followed. This has enabled us to divert the path in places, so that the vegetation can recover, and it is to be hoped that the erosion will heal. Applying and monitoring the management have become a registered project, a report on which occurs later.

Extraction of barytes at Silver Band Mine continues. A washing plant has now been erected and is in operation. 150 tons of clean barytes is being moved away by lorry each week. The mine, which has mains electricity and now the telephone, employs four to five men. The amenity aspect of both the open cast mining itself and the passage of heavy lorries on narrow country roads have given rise to adverse local comment.

c) Natural History

Reports from the Warden's Diary are made quarterly and a copy appears in the Reserve Record. These reports are summarised by J. Parkin as follows:-

A total of 74 species of bird have been recorded on the Reserve since February, and of these, 21 are known to have bred, whilst a further six probably did. The remainder are either migrants or visiting.

The most common wader, snipe, can, like dunlin, nest at the higher altitudes. Whimbrel were recorded flying over the Reserve early in September. A mong the waterfowl, teal, mallard and probably wigeon, nested, whilst goosander was seen regularly in spring.

Raptors were reasonably varied. Short-eared owl, kestrel and merlin nest and buzzard, golden eagle, harrier and peregrine were seen. Black grouse, partridge and woodcock have been recorded and the first two probably bred. Ravens are regular visitors throughout the year. The tree enclosures have encouraged birds to nest there and their shelter has provided birds in passage with resting sites. Goldcrest were recorded regularly and probably bred, whilst wryneck, willow warbler, spotted flycatcher, redstart, great tit, and blue tit were seen. Other birds in passage included chiffchaff, greenfinch, goldfinch and twite.

Among the mammals there has been a big increase in rabbits - over 40 have been shot or trapped - yet fox numbers are very low. Two litters are known to have been destroyed. Stoat and weasel were seldom seen, but mole, vole and frog were very common. Roe deer was recorded in mid-summer.

d) Survey and Research

The Reserve and Field Station are used by scientists from a number of Universities, from the Freshwater Biological Association and Merlewood Research Station. For many years Durham University has been the main source of invertebrate zoological research and this has been continued with the projects of Dr. J.C. Coulson, and Dr. J. Butterfield, while R.C. Beattie has been studying the ecology of the frog. Dr. J.B. Whittaker (Lancaster) has continued his studies of cercopidae and R. Wotton (Newcastle) returned to follow black-fly populations for a further field season. D. McDonald (Oxford) has started a project on fox behaviour. Botanical research is being continued by Professor H. Woolhouse (Leeds) with his students, M. Ashmore and D. Tattersfield, examining bog plant physiology. Other plant studies are the autecological studies of Geum spp. by Dr. K. Taylor (London) and the study of the growth of clover, perennial ryegrass and ecotypes

of other native species at low temperatures by Dr. J.H. Ollerenshaw (Newcastle). R. Hynes (London) had a further season measuring tree potential whilst periglacial movement continues to be followed by L. Tufnell (Huddersfield). Projects that have terminated and are to be published include an examination of nitrate utilisation in acidic soils (J.A. Lee et al, Manchester), and measurement of snow melt and flooding (D. Archer, Newcastle). The Freshwater Biological Association team of Dr. D.T. Crisp, Dr. P.D. Armitage and P. Cubby maintain a base at Moor House for their Cow Green Project. Dr. Crisp has continued his survey of the trout in the Reserve's streams and Dr. Armitage, co-author of a paper published this year on the stream invertebrates of the Cow Green basin, has started a small project to determine the effects of sediment-rich drainage water from the Silver Band Mine on the invertebrate fauna of the Middle Tongue Beck. C. Edwards (Liverpool Polytechnic) is a Ph.D. student with the F.B.A. section, which was assisted during the summer by two 6 month release students, D. Davidson and A. Davis (both Liverpool Polytechnic).

A.J.P. Gore (Merlewood), who has had projects at Moor House for more years than most people, continued his investigations into the ecology of blanket peat. He has set up two Autographic Weather Stations (owned by the Institute of Hydrology) close to the Climatological Station for a period of calibration. During this time the batteries and tapes are being changed by Moor House staff (R.B. Marsh). Miss L. Field (Institute of Terrestrial Ecology, Edinburgh) visited the Reserve in the course of a country-wide botanical survey, initiated by Dr. D.A. Goode, to classify blanket bog types. In the national survey of night flying moths, Dr. C. Edwards (Rothamsted) has retained the light trap, which is attended by the Warden. Staff (R.B. Marsh) take weekly records of water flow from the Trout Beck Weir for the Northumbrian Water Authority, to whom, as well as to the North West Water Authority, rainfall records are supplied regularly.

Apart from work on the Reserve (reported upon later) staff have been involved in outside survey. R. Williams reported on developments adjacent to Biglands Bog, a Site of Special Scientific Interest, west of Carlisle. In response to a request for advice a preliminary survey of part of Irthing Gorge S.S.S.I. (near Brampton) was conducted by M. Rawes and Miss L.M. Teasdale. The geological interest was mapped by Mr & Mrs Nudds, Durham post-graduate students. M. Rawes and Miss L.M. Teasdale have surveyed and produced an ecological account of the Penrith 2½" O.S. map (Sheet NY53) for the first booklet in the Cumbria Record Series produced by the Soil Survey of England and Wales. Similar surveys are being undertaken in other parts of the County. By agreement with the County Council Highways Department information on future roadworks in the County is now being obtained and a procedure established to warn local Natural History Societies so that action can be taken to protect those roadside verges of interest. Information on verges is being stored and the interest of naturalists in their management is being encouraged. Over the years we have collected much information from a variety of surveys and now the botanical data, vascular plants only at present, are being fed into a data bank. Mr. A.J.P. Gore has transferred a Creed Teletype Paper Punch and Editing Set to Moor House and this enables us to prepare data for computer sorting, using SIRON programme. We are grateful for the assistance we get from Mr. Gore and Mr. D. Lindley (Merlewood).

During July, R. Williams and J. Parkin joined a party led by Dr. J. Richards (Newcastle) continuing his survey of the plants of the northern Pennines. Several days were spent on Warcop Fell and adjoining areas and a number of new localities of interesting plants including Ingleborough rarities, were recorded. This successful survey, which started in 1972 to the north of Cross Fell, is due to end next year.

e) Advice and Education

Throughout the year people have made contact with and visited Moor House for advice and information. Two days in July were set aside for demonstrations and some 175 people attended. They included landowners, farmers, agricultural advisory officers, foresters, gamekeepers, councillors and officials of local authorities, among whom were planners, local natural history society members, university staff and local people. Laboratory and field demonstrations concentrated on the effects, on wet hill vegetation, of sheep grazing and grouse shooting, with their attendant managements of stocking, heather burning and draining. The ineffectiveness of draining - moor gripping - of high level blanket bog is particularly relevant at the present time, when a large amount of this work is being carried out on land similar to our own. The examples we have of the very limited effect that draining alone has on floristics, and the early work on the Reserve by B. Smith (UKAEA) when lateral movement of water in the peat on a 30^{o} slope was found to be less than 1 metre a year, require supporting with similar investigations at other sites, under different conditions.

Advantage was taken of the Eden Field Club's Exhibition "100 years of Natural History in the Appleby District" to exhibit a model, made by R. Williams, of the Reserve and its vegetation. An excursion of club members to Warcop Fell was led by J. Parkin, who likewise showed the Kendal Natural History Society around Moor House.

Among the parties that have visited the Station and received instruction have been biologists from Lancaster University, under Dr. J.B. Whittaker, who ran a 10 day residential course, which included a number of student projects; biologists from University College London, with Dr. K. Taylor, undertaking field work on the west side of the Reserve and visiting research sites, whilst they were staying at Brathay Field Centre; a Swedish party from Stockholm staying overnight; and day visits by members of the Plant and Soil Sciences (Newcastle), Durham Zoology and Extra-Mural Departments, Cumbria College of Agriculture and Forestry, St. Peter's College of Education, Birmingham, and Sunderland Technical College.

Seven papers in the Moor House Occasional Paper Series have now been produced, the most recent dealing with freshwater biology (Dr. D.T. Crisp), red grouse (P. Taylor and M. Rawes), and history (D. Welch). An account of the botany is in draft. The series has proved a useful means of publicising results and it is hoped that funds will enable an improved publication to be made in future.

Outside the Reserve the survey of part of Irthing Gorge S.S.S.I. gave wildlife and geological information that was displayed on notices sited in the grounds and inside the Spa Hotel. This was a joint effort with the Ministry of Agriculture (A.D.A.S.) who had been called in first, to educate a largely urban public. Apart from the large number of guests, many people visit these grounds in the summer.

The British Gas Council were given advice on methods of re-vegetating land in Cumbria, especially moorland, disturbed by the laying of a 36 inch diameter gas pipe line, from Carlisle to Kendal.

f) Visitors

The Swedish party was led by Dr. H.C. Wallentinus (Stockholm University) and included a member of the Swedish Geological Survey, one from the Swedish Museum of Natural History as well as three other members of the Botanical Institute, Stockholm University. Dr. Graham Arnold (CSIRO, Australia) visited us to discuss the effects of sheep grazing on upland vegetation. Mr. A.O. Chater (Leicester) brought Dr. Jonsell (Uppsala, Sweden) to see Alopecurus alpinus, whilst Dr. O.W. Heal brought Drs. F & P Bunnel (University of British Columbia) to see the IBP site and discuss sheep production. Among other visitors was J. Jenkins, School of Botany, Melbourne University and Dr & Mrs H. Mauritsch, Leoban University, Austria.

Mr. D.H. Wood (Land Agent) was the sole N.C.C. visitor.

g) Staff

In October, 1973, J.P. Houlton, who had been Reserve Warden for 18 months, was transferred to the South West Region. J. Parkin was appointed in his place and took up post in February. He was joined by his family the following month. In June, R.B. Marsh passed a promotion board and was promoted to Scientific Officer.

M. Rawes and R. Williams attended the Hill Land Use and Ecology Discussion Group meeting in Galloway and M. Rawes went to the British Grassland Society Summer Meeting at York. Field Study Centre Courses were taken by Miss L.M. Teasdale on 'Difficult Plants', at Preston Montford, and by P. Holms on 'Flowers of the Limestone' at Malham Tarn.

II. SCIENTIFIC - Moor House Staff

Despite poor weather a considerable amount of field work has been completed particularly in respect of the routine botanical recording of specific sites. Apart from the regular point quadrat analyses, charting the vegetation has been repeated, in some cases, after a lapse of 19 years. These maps provide good supporting evidence for the point quadrat, the latter giving information on species change and the former showing the development often of a more precise vegetation pattern, in the sheep-exclosures. Mapping of the grouse survey areas has also proved useful for comparative purposes, and a large scale vegetation map of the most popular ski-run, an East-facing gulley on Great Dun Fell should permit the monitoring of this site to be more accurate than with the previous photographic recording. Little of this charting would have been possible without the help of students.

Measurements of tree growth have not been made in recent years, but in the current year this is being remedied.

Only in one enclosure, Nether Hearth, have trees been measured as yet and the results are summarised as follows:-

Lodgepole pine (P. contorta) - mostly 18 years old

Average tree height	3.2 metres
Average height increment 1974	25.5 cm
Average girth (at 1.35 m)	16.4 cm

Mountain pine (P. mugo) - mostly 18 years old

Average height of the 27 tallest trees	1.7 metres
Average height increment 1974	15.4 cm

Growth would appear to have been much better than in some previous years, lodgepole having grown 15.4 cm in 1968 and only 6.0 cm in 1963.

The severe mid-summer frost killed a number of sitka and destroyed growth of others and of larch. 200 lodgepole and mountain pines were planted in the spring as well as a number of local birch, rowan and willow.

A few years ago, in conjunction with the Ministry of Agriculture Advisory Service, a trial of bred grass species and varieties produced some results showing response to adverse conditions that was of value agriculturally as well as ecologically. This year, mainly to provide extra feed for the Moor House sheep, a trial of 9 varieties of turnip, is also giving interesting results. The turnips were direct sown on to grassland killed by paraquat, and samples are being taken for root and leaf weight whilst records are made of frost resistance, flowering and root shape. In September, the overall average turnip (root and top) live weight was 416 g, varying from 640 g with Green Globe to 168 g with Wallace. Debra, a Dutch turnip, one of the so-called 100-day turnips because of their quick growth, averaged 620 g. Yields will continue to be recorded and the year's results will be made available to anyone interested.

The following students have helped us over the past year:- Duncan Campbell, (late Portsmouth Polytechnic) computed point quadrat data; Tom Spencer (Cambridge) carried out mapping and analysis of the grouse survey areas; Ro Scott (York) assisted with botanical work, mapping and quadrat analyses; Kathryn Heslop, Morag Jones and Julian Ustazewski (all Leeds) have assisted by mapping vegetation of eight sites and recording botanical quadrats; and Lawrence Heslop (late Cambridge Polytechnic) undertook a vegetation survey of the most used ski run on Great Dun Fell and produced a large scale map.

a) Climatology (R.B. Marsh)

The weather summary for 1973 is to be found in the appendices. This is the fourth year that the winter temperature has been above average for the months January to March.

The year (October to September) can be divided into three distinct periods, the first being the three months October to December inclusive. In this period mean temperature was below average, air frosts totalled 46 as compared with the average of 39, and ground frosts totalled 68 compared with an average of 49.

During the second period, January to April inclusive, the mean and earth temperatures never fell below average. Days of snow lie numbered only 21 days compared with the average of 50 days. On the other hand rainfall for January was 365.1 mm, just over double the mean of 177.9 mm. This was the second highest measurement for January since records began in 1953. By contrast the rainfall for April was 16.4 mm, which is the lowest rainfall ever recorded for any month since records began.

In the third period, May to September, mean and earth temperatures were below average for the whole period and on 28th June a dry and severe frost was recorded. This low temperature did a lot of damage to vegetation.

The air minimum was -4.8°C while the grass minimum recorded -12.3°C. Although the grass minimum is about the same as June 1973 (-12.4°C), the air minimum in 1973 was only -1.1°C. From the bi-metallic thermograph chart it can be seen when the freezing started and ended, for the air frost and ground frost would follow a similar pattern. In 1973 the length of freezing was for one hour (1200-0100) while this year the frost lasted for approximately eight hours (2100 on the 27th to 0500 on the 28th).

b) Studies on the interaction between sheep and vegetation (M. Rawes, R. Williams, R.B. Marsh and Miss L. Teasdale)

The project title covers a number of studies all aimed at following the effect of sheep and management on the Reserve habitats. Particular emphasis is placed on the vegetational responses. The studies are grouped as follows:-

1. Effects of the present sheep grazing regime

The number of sheep on the Reserve has remained relatively constant over the past 20 years, the only changes being in the increase in the number of grey-faced lambs (Border Leicester x Swaledale), the removal of a Cheviot flock and the appearance of Rough Fells.

During the summer botanical analyses have been repeated at a number of the representative sites, and, although the results are awaiting statistical examination, no significant change is expected.

2. Effects of removing sheep grazing

All the grassland sites and some others have been examined. The high-level grasslands on Knock Fell (Agrostis-Festuca vegetation), Little Dun Fell and Hard Hill (both Festuca swards), and the poor grasslands Nardus and Juncus squarrosus (Moor Rush) have been studied. The first three of these exclosures have been fenced for nearly 20 years and the others for eight. A flush site by Moss Burn, enclosed for two years, and two high-level blanket bog sites, one near the Silver-Band track and the other by Troutbeck Head, both erected in 1966, have been investigated. The vegetation has been re-mapped in most cases and point quadrats repeated.

Moor House Weather - October 1973 - September 1974

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Year
Maximum °C	8.3	4.4	3.2	4.0	3.5	4.1	8.9	10.8	12.8	13.4	13.8	10.0	8.1
(20 years)	(9.7)	(5.2)	(3.4)	(2.1)	(1.7)	(4.1)	(7.0)	(10.8)	(13.8)	(14.7)	(14.4)	(12.7)	(8.3)
Minimum °C	2.4	-1.1	-2.2	-0.3	-0.4	-1.6	-1.9	2.2	4.2	7.1	7.2	4.9	1.7
(20 years)	(3.9)	(0.2)	(-1.8)	(-2.6)	(-3.6)	(-1.6)	(-0.1)	(2.6)	(5.4)	(7.1)	(7.3)	(5.9)	(1.9)
Mean °C	5.3	1.7	0.5	1.9	1.5	1.3	3.5	6.5	8.5	10.3	10.5	7.5	4.9
(20 years)	(6.8)	(2.7)	(0.8)	(-0.2)	(-0.9)	(1.2)	(3.4)	(6.7)	(9.6)	(10.9)	(10.9)	(9.3)	(5.1)
Earth temperature °C	7.2	4.7	2.3	2.6	2.6	2.5	4.4	6.5	9.3	10.4	10.9	9.2	6.0
(20 years)	(0.8)	(4.7)	(2.7)	(1.6)	(1.5)	(1.9)	(3.8)	(6.9)	(10.0)	(11.6)	(11.7)	(10.4)	(6.2)
Rainfall (mm)	118.7	116.1	233.3	365.1	214.8	151.8	16.4	75.2	118.0	154.2	91.6	189.3	1844.5
(20 years)	(192.6)	(203.5)	(206.2)	(177.9)	(150.5)	(126.1)	(124.2)	(127.9)	(110.8)	(142.8)	(168.3)	(156.7)	(1887.5)
Days with sunshine	2.05	2,50	0.80	0.45	1.31	2.96	6.44	6.13	5.99	3.80	4.18	2.98	3.30
(20 years)	(2.63)	(1.33)	(0.93)	(1.02)	(1.76)	(2.73)	(3.98)	(5.15)	(5.79)	(4.60)	(4.28)	(3.41)	(3.13)
Days with air frost	8	17	21	14	14	24	24	7	1	0	0	3	133
(20 years)	(4)	(14)	(21)	(23)	(22)	(21)	(15)	(7)	(1)	(1)	(0)	(2)	(131)
Days with ground frost	15	26	27	20	21	27	28	16	11	4	4	9	208
(20 years)	(9)	(18)	(22)	(25)	(24)	(24)	(19)	(12)	(6)	(4)	(3)	(5)	(171)
Days with snow lying	0	2	13	9	8	12	0	0	0	0	0	0	44
(20 years)	(0)	(6)	(11)	(16)	(18)	(12)	(5)	(1)	(0)	(0)	(0)	(0)	(68)

Figures in brackets = average

One of the most interesting sites in this series, Knock Fell (2400 ft, 732 m O.D.) was extensively damaged by rabbits towards the end of the summer. This site has been intensively studied over the years and now the vegetation has been grazed severely. Rabbit netting has been erected.

A preliminary examination of the data collected from each site follows:-

Knock Fell

After the erection of a rabbit-proof fence, 250 stratified point quadrats were analysed to try to assess the effects of rabbit grazing. The vegetation height is now virtually restricted to the lower two strata (20 cm), whereas previously it grew to 40 cm, with few inflorescences remaining. A count in 50 x 1 m^2 quadrats produced an average of 73 rabbit pellets/m^2 = 5.8 g/m^2 dry wt. of dung.

Little Dun Fell

A repeat of the 1956, 1962, 1970 points was done, especially to obtain data on the status of the cryptograms. The results confirmed the angiosperm records for 1970 and showed a great reduction in bryophyte and lichen species since 1962. Vegetation maps of this and the small introduction enclosure nearby (see section c) below) were repeated and are to be compared with the previous maps and the point quadrat records.

Hard Hill

The vegetation was re-mapped to be compared with that of 1954.

N1 and J1 - the Nardus stricta and Juncus squarrosus dominant grasslands.

The apparent increase in flowering performance after enclosure was recorded using counts of the number of inflorescences in 25 x 1 m^2 quadrats, and compared with the performance as measured by point quadrats.

In J1, Juncus squarrosus, although almost eliminated from the sward produced twice as many inflorescences/hit as in the control. Deschampsia flexuosa and Eriophorum vaginatum also produced more inflorescences.

In N1, there was no change in the flowering performance of Nardus stricta whereas most other species produced more inflorescences.

	Juncetum squarrosi				Nardetum			
	Enclosed		Grazed		Enclosed		Grazed	
	Inflor/ 25 m^2	Hits/ 250 pts	Inflor/ 25 m^2	Hits/ 250 pts	Inflor/ 25 m^2	Hits 250 pts	Inflor/ 25 m^2	Hits/ 250 pts
Juncus squarrosus	21	23	234	442	59	19	24	6
Nardus stricta	-	-	-	-	659	1219	559	1008
Deschampsia flexuosa	1670	1224	283	527	846	-	709	-
Festuca ovina	683	330	1263	581	1216	543	2244	628
Agrostis spp.	-	-	-	-	126	187	2	204
Deschampsia cespitosa	-	-	-	-	30	17	-	-
Eriophorum vaginatum	193	828	32	286	-	-	-	-
Carex spp.	6	67	5	57	43	31	15	8
Luzula multiflora	-	-	-	-	38	3	69	19

These interesting results may repay further study of seed production and viability, and potential inflorescence production and consumption by herbivores in the grazed sward.

Johnny's Flush Enclosure

The area to be enclosed and the control plot, were surveyed in 1972 and the fence erected in April 1973, giving two seasons growth in the absence of grazing. The point quadrat layout was reduced from 2 x 10 pin frames in 30 randomly chosen m^2 quadrats to 1 x 5 pin frame in all 60 quadrats. The stratified data showed a 38% increase in total hits in the enclosure and a change in the structure of the vegetation. In 1972 examination of each 10 cm stratum in the height of the vegetation showed that 87% of the hits fell within the lowest stratum (Stratum 4) and 11 and 2% in the two above. Now, however, the order is 49, 37, 13 and 2%, the lowest containing much undecayed dead material.

	Stratum	1974 Encl.	1974 Grazed	1972 Encl.	1972 Grazed
Cyperaceae	1	24	0	0	1
	2	173	2	8	8
	3	414	39	94	94
	4	359	494	506	518
	Total	970	535	608	621
	% of Whole	51%	40%	44%	40%
Juncaceae	1	15	6	6	11
	2	25	8	12	7
	3	143	44	38	31
	4	211	304	252	274
	Total	394	362	308	323
	% of Whole	21%	27%	22%	21%
Gramineae	1	0	0	0	0
	2	27	3	4	10
	3	149	46	13	33
	4	216	257	298	371
	Total	392	306	315	414
	% of Whole	20%	23%	23%	27%
Other Angiospermae	1	1	0	0	0
	2	1	0	0	0
	3	12	5	5	0
	4	149	135	155	176
	Total	163	140	160	176
	% of Whole	8%	10%	11%	12%
Total		1919	1343	1391	1534

Stratified hits per 300 pins in each 10cm stratum

The 6 species of Carex: Carex nigra, C. echinata, C. demissa, C. panicea, C. dioica, C. pulicaris have shown the greatest increase in cover and have all fruited well. Several 'other angiosperms' Alchemilla glabra, Caltha palustris and Geum rivale which have been morphologically 'dwarfed' by continuous grazing have grown to more usual size in the enclosure and others Epilobium spp., Prunella vulgaris, Polygonum viviparum, Saxifraga stellaris and Valeriana dioica have also produced flowers. Saxifraga hirculus produced about 70 flowers (cf. 10 in the control) and grew to 20 cm in height although this performance is expected to decrease in time. Liverwort cover remains unchanged but the acrocarpous mosses have decreased. An analysis of the same 150 points in the 1972 and 1974 control showed that only 18% of species hits were recorded at the same point in both years.

Silverband Enclosure

This enclosure was erected in 1966 on a degraded Eriophoretum with much dissected bare peat. The almost complete absence of Calluna vulgaris and its replacement by Eriophorum vaginatum may be due to the sheep grazing and to the effects of altitude (2250 ft, 686 m). After 8 years enclosure, the few original Calluna plants have spread so that heather now covers 0.38% (1.3 m^2) of the ground. Much bare peat remains but Narthecium ossifragum, Scirpus cespitosus and Empetrum nigrum have all formed extensive patches. Carex nigra has increased slightly and with Narthecium puts down a litter layer which may stabilise the surface and further the development of an interesting community. Lichens and mosses have increased slightly; Sphagnum rubellum and S. papillosum hummocks being very prominent. 500 stratified point quadrats were completed in the enclosure and control and vegetation maps drawn on a scale of 2 cm = 1 m of both enclosure and control.

Troutbeck Head Enclosure

At 2250 ft (686 m) on the more sheltered east side of the summit ridge there is more Calluna in the grazed control (cover 1%) and this has increased since 1966 when the enclosure was erected to 9.5% (31.9 m^2). Empetrum and Deschampsia flexuosa have both increased, but no other species have changed as much. Sphagnum hummocks have again developed in the absence of sheep.

The bare peat, less than at Silverband, has been reduced by colonisation around the edges. 500 stratified point quadrats, of the same lay-out as Silverband, were completed and a vegetation map of the enclosure strengthens the comparison of vegetational change, rather than of individual species, over eight years.

3. Effects of grazing alterations, burning and draining

(i) Blanket bog - since 1968 a series of plots have been receiving different sheep stocking rates, and treatments of burning and draining. There are other trials of longer establishment where the effect of two burning regimes and draining are being studied in the long term.

The stocking, which is recorded in the number of sheep-hours, is approximately similar each year whilst the vegetation changes are recorded by point quadrats and the observation of incoming species.

The heavy grazed plots are grazed at the rate of 3.43 sheep/ha each year, the light grazing plots at 0.37 sheep/ha compared with range grazing of 0.13 sheep/ha. The analysis of the heavy grazing plot was repeated and showed little change from 1971 and 1972. There is a gradual increase in Cryptograms, establishment of Calluna seedlings, and natural introduction of several plants of Agrostis spp., Anthoxanthum odoratum, Festuca ovina, Juncus squarrosus and J. effusus; these have been individually monitored since 1968 and are now featuring in the point quadrat records.

(ii) Juncus squarrosus dominated grasslands - The reduction of Juncus squarrosus, an unpalatable and common plant of upland grazings, is well known when sheep are removed from such swards (Rawes & Welch, 1969), but the effect of increasing the usual grazing pressure is not. Sheep have been put onto a small area (18 x 18.5 m) of this vegetation and a simple lay-out of randomly placed 0.5 m^2 quadrats record changes in species. The stocking this year has been 1945 sheep hours or 12.2 sheep/ha, which is 9 times greater than the free range grazing pressure of 1.3 sheep/ha. Whilst the appearance, both in sward height and the dark green colour of Carex nigra, are different from the open fell sward there has been no change yet in species composition. The indications are that there will be considerable change in the future.

c) The establishment of natural grassland communities (M. Rawes and Miss L. Teasdale)

Montane and arctic-alpine plants were introduced to four enclosures in 1955 and 1956.

In Rough Sike enclosure (560 m O.D.) there has been little change over the past year and most introductions have maintained their stations. The dwarf willows (Salix arbuscula, S. herbacea, S. phycilifolia and S. reticulata), the saxifrages (S. aizoides and S. oppositifolia) and alpine lady's mantle (Alchemilla alpina), alpine saussurea (Saussurea alpina), roseroot (Sedum roseum) and alpine cinquefoil (Potentilla crantzii) have all done particularly well despite the increase in rabbits.

However, the depredations of the rabbit pressure on Knock Fell (747 m O.D.) has placed the existence of a previously flourishing enclosure in jeopardy. Part of the site is a limestone sink hole, where most of the plants have been introduced, and it is virtually impossible to exclude rabbits. A number have been trapped and shot but the local population is large. The willow (S. caprea) has been severely grazed, holly fern (Polystichum lonchitis) has disappeared and alpine lady's mantle (Alchemilla alpina) grazed so hard as to prevent flowering.

51 plants were introduced to Hard Hill (678 m O.D.) in 1955 and 17 more in 1956. Only one transplant remains alive and that surprisingly is a rowan, which never grows above 20 cm, a true bonsai. The Hard Hill environment is particularly harsh and probably only suitable for dwarf shrubs initially until some cover is provided.

The site on Little Dun Fell (820 m O.D.) is also severe; but the steep north-east facing slope provides shelter from the prevailing winds and the soils are marginally more favourable. Nevertheless of the 34 plants introduced only four remain. They are alpine lady's mantle (Alchemilla alpina), willow (Salix herbacea) and moss campion (Silene acaulis); both the latter two species appear to be growing in suitable situations.

d) Studies of Red Grouse and Moor Management (M. Rawes and P. Holms)

An Occasional Paper (No. 6) has been produced and gives the background and some results of grouse studies at Moor House over the past 20 years.

This year observations and recording of the number of grouse have continued with the routine spring and summer counts of birds, and of nests and clutch size. The previous census areas have been used, but have been modified and extended to give a better cover of the Reserve, and to allow a comparison to be made of two parts, which experience has shown to have consistently different grouse numbers. In these two areas, the eastern slopes of Hard Rigg and Green Burn-Force Burn, sample areas of 160 ha (400 ac) have been marked, and further divided so that one half, 80 ha (200 ac) in each is subjected to a burning programme of the recommended type with numerous small burns.

1. Area Survey

This year an initial description of the two areas has been made by Tom Spencer, with botanical assistance by Miss Ro Scott. Vegetation maps were constructed, on a scale of 24 inches to 1 mile, using aerial photographs, the map of Eddy, Welch & Rawes (1969) and ground survey. The extent of the vegetation types was found to be as follows:-

	% of area	
	Hard Rigg	Green Burn- Force Burn
Calluneto-Eriophoretum	77.8	88.8
Recolonised peat	13.1	1.2
Eroding bog	6.0	1.8
Sphagneto-Juncetum effusi	1.2	2.7
Juncetum squarrosi	0.1	0.4
Nardetum	0.8	3.9
Agrosto-Festucetum	-	1.1
Festucetum	-	0.3
Made ground (mining hush)	1.0	-

The mapping has been supplemented by cover estimates of plants in 100 x 2 m^2 quadrats on each area.

Examination of the quadrats (list below) shows that in Green Burn only 5% of the quadrats fell on 'moor edge' compared with 24% on Hard Rigg. 'Moor edge' is a relatively dry but narrow strip habitat, where the bog ends abruptly often at gulley or stream dissections. Heather growth is commonly good in these situations and always appears more green than elsewhere.

Comparison of the botanical composition of blanket bog on Hard Rigg and Green Burn. Estimates of percentage cover, given a rating of 0 to 5, at intervals of 20%. Average rating/100 x $2m^2$ quadrats.

	Hard Rigg	Green Burn-Force Burn
Calluna vulgaris	3.8	3.7
Empetrum nigrum	1.7	1.2
Erica tetralix	0.1	0.1
Eriophorum angustifolium	0.8	0.6
E. vaginatum	2.8	3.1
Rubus chamaemorus	0.4	0.6
Trichophorum cespitosum	0.4	0.2
Vaccinium myrtillus	0.4	0.1
V. vitis-idaea	0.3	0.1
Listera cordata	present in 1 quadrat	present in 5 quadrats
Narthecium ossifragum	2	3
Dicranum scoparium	63	0
Plagiothecium undulatum	48	23
Polytrichum commune	4	19
Rhytidiadelphus loreus	45	0
Lophozia ventricosa	6	0
Cladonia arbuscula	8	0
C. impexa	80	23
C. squamosa	32	0
Cladonia spp.	0	30
Parmelia physodes	35	12

The amount of recolonised peat and 'moor edge' vegetation is greatest on Hard Rigg where 24% of the quadrats fell on this habitat compared with 5% on Green Burn. This along may be significant in explaining the difference in grouse numbers. The greater amount of broken ground on Hard Rigg also gives grouse territories of better cover and diversity in relief, whilst water courses (Hard Rigg 7.6 miles/sq. mile, Green Burn 4.8 miles) are similarly important.

The presence of outcropping limestone at the head of Hard Rigg may be an important factor in influencing the nutrient content of vegetation and stream water. Preliminary analyses of the Ca content show a very wide variation (range 0.5 - 36 mgl^{-1}) in the 33 water samples taken, so the results were found to have little meaning and the chemical aspects require further attention. However, estimates of the extent of bedrock types (see below) within each area showed differences: there is more limestone on Hard Rigg although Green Burn has extensive Whin Sill and no sandstone.

	% of total	
	Hard Rigg	Green Burn
Limestone	20.7	15.1
Shale	53.3	50.5
Sandstone	25.3	-
Whin Sill	-	30.2
Alluvial fan	0.7	-
Alluvium	-	4.2

Chemical analyses and the measurement of green shoot production of heather, the main food of the grouse, have been made by a number of research workers at Moor House, especially during the IBP, and differences have been found between years and between sites. Students from the Department of Botany, University College of London, under Dr. K. Taylor, sampled Calluna on three Grouse census areas in September, 1973, but only one was within the Green Burn area. They found significant differences in the weight of shoots and in all mineral elements except Ca and Na.

Census area	Wt. of shoots g/m^2	Total above-ground standing crop g/m^2	% on dry weight basis N	P	K	Mg	Na	Ca
Burnt Hill	54.8	488	1.053	0.063	0.428	0.128	0.069	0.475
Green Burn	121.6	740	1.22	0.095	0.545	0.170	0.064	0.460
The Drive	72.0	551	1.21	0.082	0.488	0.163	0.069	0.470

These figures do not suggest that Green Burn is the poorest part of the Reserve.

In 1974, a comparison was made of heather flower abundance and terminal shoot length. The abundance of flowers should be related directly to length of shoots, flowers being confined to the current year's growth. On Hard Rigg the number of flowers was double that of Green Burn but 70% of the figure recorded by G.I. Forrest in 1968, a year of heavy flowering. On the other hand in this instance, shoot length was 1½ times less on Hard Rigg than Green Burn, possibly an effect of frost retarding growth more on Hard Rigg.

2. Grouse population study

Counts of adults were carried out in the spring, of nests and eggs in the summer and to establish breeding success in July.

A trained pointer was lent by Mr. D. McGarry (Selside, Kendal) from whom a puppy was acquired which will be used in future. 12 sampling areas were counted including the new areas on Hard Rigg and Green Burn. The spring count showed there to be an overall density of 1.2 birds/ha (slightly more than in 1973), varying from 0.8 on The Drive to 1.7 at Bog End. The Hard Rigg sample areas had 20% more birds than Green Burn.

Overall clutch size was low at 5.4 eggs/nest (average of 8 eggs over previous 3 years) with a higher than 1971 average egg weight of 24.5 g and size of 46.2 mm. Hatching success of 96.4% was very good and better than in 1971 (94.5%) and 1972 (94.1%).

However, breeding success was poor, the final overall ratio of young to old birds being 1.8 : 1 (2.9 : 1 in 1973). Green Burn 2.0 : 1 was 20% better than Hard Rigg, which was below the overall average.

Thus the results were poor after a run of three good years with very large numbers of grouse. The low number of eventual breeding birds was probably due to the poor condition of the heather, much of which, unprotected by snow cover, had been browned by low temperatures, dry east winds and sunshine in March dehydrating the plants. Conditions in April and May were even worse and the food supply reduced to minimal quantities and quality. Later in the summer the heather received a further set back when the frost of 28 June killed the shoots over many acres of moor. In the latter part of the season the heather has made a good recovery.

c) Pennine Way (R.B. Marsh)

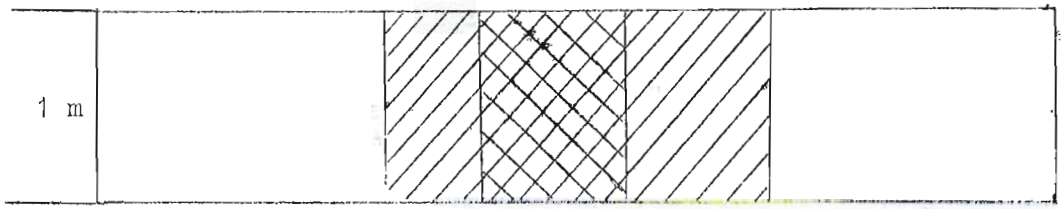
The Pennine Way was opened officially in 1965, but most of it has been used as such since 1955, as a 250 mile long distance footpath. This pathway runs through the Moor House National Nature Reserve from Swindale Beck (701286) to Crowdundle Head below Cross Fell (699338) a distance of approximately 4.4 miles (7.1 km) rising from 1300 ft (396 m) to 2780 ft (847 m) (See map).

Each year the number of walkers has increased and the pathway has gradually deteriorated. In the spring of this year it was decided to alter the route slightly, to allow recovery and prevent serious erosion. The route was marked with signs (carved boards with white letters on a blue background) made at Ainsdale Nature Reserve, and erected before the Easter holiday. After about six weeks, the new pathway was visible, although some walkers ignored the signs and used the old path.

Four sites along the pathway (See map) were selected for monitoring. The four sites were: (1) a wet peat area at about 2500 ft (766 m) between Little Dun Fell and Crowdundle Head, (2) a steep slope on the side of Little Dun Fell at 2,600 ft (792 m), (3) a Juncus squarrosus area on Knock Fell at 2425 ft (739 m), and (4) a Nardus stricta area at about 2,300 ft (701 m). At each site, four plots were chosen, on (1) the new path, (2) an old path no longer used, (3) an old path still used, and (4) a control area. At each site the plots examined were 1 metre x 5 metres, the pathway being in the centre. The following features have been measured:- aspect and slope, width of path and % cover by vegetation. These will be repeated at the start and end of each season. Some results obtained this year are shown overleaf.

A limited census in which 436 hikers were recorded, was made by members of staff on the fell. The results are being compared with information from other sources such as numbers staying at hostels. One result however, requires no substantiation, most walkers, 80% are at this stage of the Pennine Way, walking north.

12 June, 1974

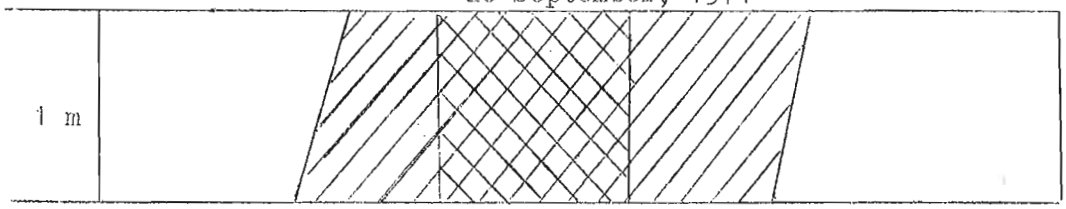


Distinct path

Normal sward height

Trampled shorter vegetation

20 September, 1974



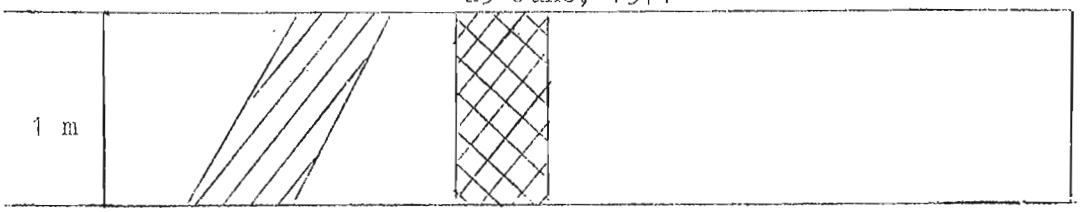
Distinct path

Normal sward height

Trampled shorter vegetation

Site (3) - Juncus squarrosus sward

25 June, 1974

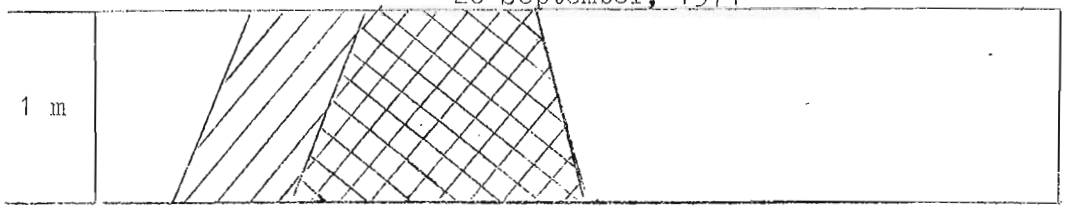


Distinct path

Normal sward height

Old path

20 September, 1974



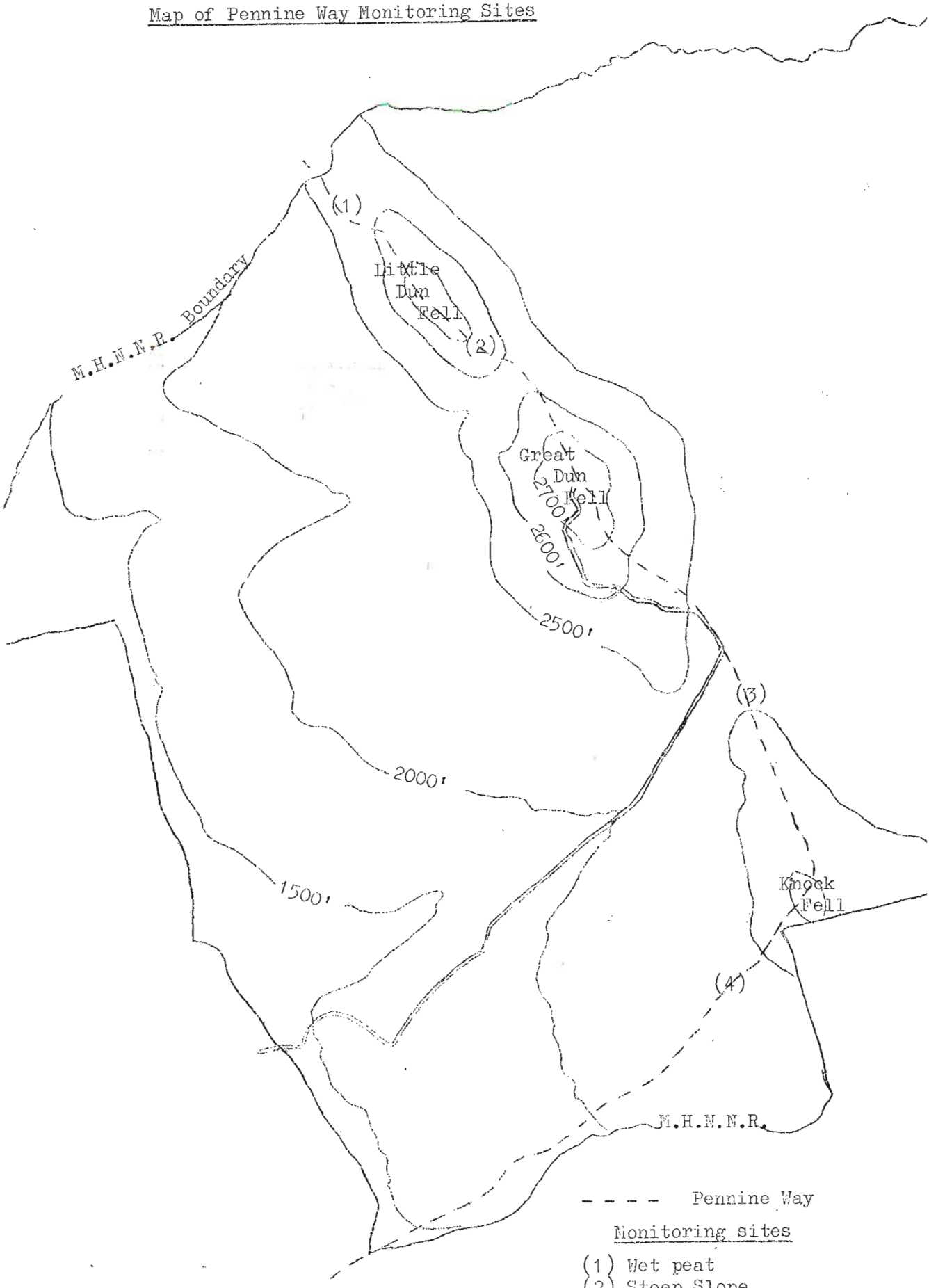
Distinct path

Normal sward height

Old path

Site (4) - Nardus stricta sward

Map of Pennine Way Monitoring Sites



III. RESEARCH BY MERLEWOOD STAFF

a) Plant ecological studies on peat (A.J.P. Gore)

1. Factors limiting plant growth on peat

The computational work on this project has been completed to a stage where a first draft has been started.

2. Productivity of blanket bog vegetation

A paper entitled "An experimental Modification of Upland Peat Vegetation" has been accepted for publication in the Journal of Applied Ecology. This paper describes an experiment in which clipping was used to simulate a range of levels of removal of blanket peat vegetation by grazing and burning. Replacement of Calluna vulgaris by Eriophorum vaginatum was more pronounced on more sloping, shallower peat. Rubus chamaemorus declined under the more frequent clipping treatment (once per year over 13 years) on the flatter, deeper (and wetter) peat but persisted without appreciable change on more sloping peat under the same treatment. The roles of physical stability of the peat surface and mineral nutrition are discussed.

3. Erosion reclamation

Willows (Salix caprea ?) have appeared in several of the enclosures concerned with peat reclamation. Records suggest that these plants are derived from seed which arrived by chance at different times between 1959 and 1967. Willows are reported present outside the experimental enclosures in two places on the Reserve but only in the last four years have the plants grown to sufficient size (some over 6 feet high) to merit specific mention.

4. Some preliminary studies on the movement of water in blanket peat have been initiated and two automatic weather stations supplied by the Institute of Hydrology, Wallingford have been installed at Moor House.

IV. RESEARCH BY THE FRESHWATER BIOLOGICAL ASSOCIATION

a) Studies on freshwater fauna - fish (D.T. Crisp)

Almost the whole of the fieldwork done by the FBA Cow Green Unit now occurs at Cow Green, though the use of laboratory facilities at Moor House continues and is of great importance.

During the autumn of 1973 some very large trout were seen in the Tees some distance upstream of Tees Bridge. Tagging has shown that some (possibly all) of them are spawners from Cow Green reservoir. Survey of fish populations in the River Tees above Tees Bridge were made in May, August and October of 1974 and continuation of this programme for several years is proposed.

Publications

1. CRISP, D.T., MANN, R.H.K. & McCORMACK, JEAN. (in press) The populations of fish at Cow Green, Upper Teesdale, before impoundment. J. appl. Ecol.

2. CRISP, D.T., MANN, R.H.K. & McCORMACK, JEAN. (in press) The populations of fish in the River Tees system on the Moor House National Nature Reserve, Westmorland. J. Fish Biol.

V. RESEARCH BY UNIVERSITIES

a) A study of the factors limiting the soil fauna on blanket bog. (J.C. Coulson & Mrs J.E.L. Butterfield, University of Durham)

This project has been designed to investigate the factors limiting the soil fauna on blanket bog. Evidence exists which suggests that the limiting factor could be the low levels of available nitrogen or phosphorus on the peat. In order to investigate this and the possibility that herbivores and decomposers select their food according to its mineral content, a series of experiments have been set up and these are still in progress.

1. Approximately 50 m^2 areas of blanket bog and Juncus squarrosus sward at Bog End were fertilised in 1972 with applications equivalent to 5 g/m^2 phosphorus and 10 g/m^2 nitrogen (applied separately and in combination). Population densities of tipulids and enchytraeids have been monitored on these sites, whilst the effects on the tipulids expressed in larval size and fecundity are being investigated.

The most marked effect has been found in Tipula subnodicornis where by the autumn, 1973, the population densities on the nitrogen treated areas were more than twice those on the phosphate and control areas.

2. Litter bags containing vegetation from fertilised and unfertilised areas have been placed on a series of sites in order to compare the attractiveness of the N and P enriched plant material to the animal decomposers. Bags of two different mesh sizes, one allowing access to the soil animals the other excluding them, have been used in order that the role of the soil fauna in the decomposition of the vegetation can be evaluated

b) Studies on Homoptera (J.B. Whittaker, University of Lancaster)

Intermittent sampling of the heather psyllid (Strophingia ericae) has been continued as part of a long term project concerned with the population dynamics of upland Homoptera.

c) Studies on blackfly larvae (Diptera: Simuliidae) in Moss Burn (R.S. Wotton, University of Newcastle upon Tyne)

This summer, work has been concentrated on the lower part of Moss Burn where population estimates were again obtained by removal collecting.

Four species: Simulium vernum Macquart; S. brevicaule Dorier & Grenier; S. monticola Friedrichs; and S. nitidifrons Edwards were common as in 1972. This year, however, S. nitidifrons was the least common of the four whereas it was the second most important species in 1972. S. vernum continued to be the most numerous species.

The pattern of abundance through the summer was very different in 1974 with no peak of numbers in early August. In fact the numbers of larvae present remained at similar low levels throughout the study period. (Mean population estimates were 43 larvae m^{-1} stream length this year and 83 larvae m^{-1} in 1972).

Further data from this summer will have to be analysed before the detailed life-histories of the four species can be determined but empirical observation suggests that there were fewer cohorts in S. monticola this year than in 1972. (One cohort extended from early July to mid August in 1974 with no evidence of further hatching in early August as occurred two years ago.)

In 1972, the production of all species in the lower part of Moss Burn in August was 13.2 mg dry weight m^{-1} stream length so this year the figure for the equivalent period will probably be smaller still.

d) The effect of altitude on the ecology of the frog (Rana temporaria) (R.C. Beattie, University of Durham).

Ponds ranging in altitude from 61 to 823 m were studied between Durham and Moor House.

The date of spawning in days after 1 January (y) was related to altitude (x) by the following relationship:

$$\text{Spawn date, } y = 0.0499\ m + 59.7192 \quad (r = +0.8385,\ p < 0.001)$$

Spawning was later by approximately five days, for each 100 metre increase in altitude. Spawning on Great Dun Fell occurred about 40 days later than spawning in the Durham area.

Eggs taken from ponds at different altitudes were cultured at constant temperatures. Eggs from higher altitudes developed faster. The difference varied according to the stage of development. For example, during the period of development from late yolk stage to the gill bud stage, eggs from Great Dun Fell developed 23% faster than eggs from Durham, when both were kept at 10°C. This, presumably, is an adaption to breeding under the colder conditions at higher altitudes.

Observations suggest that, compared to lowland frogs, those frogs from higher altitudes tend to spawn in the shallow regions of a pond. This may be a further adaption, allowing maximum use of solar radiation to hasten development.

The effect of altitude on larval growth weight and mortality, is at present being studied.

e) Studies on the photosynthesis and water relations of Calluna vulgaris. (M.R. Ashmore, University of Leeds).

Measurements of photosynthesis, water potential and growth rates have been made throughout this season using the methods described in previous annual reports. The apparatus used to measure photosynthesis has been modified so that the air leaving the leaf chamber passes through an aluminium hydroxide sensor which measures the water vapour pressure of the exit air. From this, given the vapour pressure of the air entering the chamber and the leaf temperature, it is possible to calculate the stomatal resistance of the enclosed tissue. The results obtained so far indicate that on days of high iradiance there is a considerable increase in stomatal resistance in the middle of the day.

An attempt has been made to measure the extension growth of Calluna shoots over short periods of time using a set of auxanometers. Although these were originally designed for use with barley leaves, some useful data has been obtained and it is hoped that this, together with the longer term growth measurements, will provide information on the relation between growth rates and environmental parameters in Calluna. Also these growth measurements will provide data with which to test any models of growth processes in Calluna constructed on the basis of an analysis of the physiological data.

The Grant temperature recorder has again been run throughout the summer. The six probes previously sited under a Juncus tussock have been removed and are now being used for measurements in and under Sphagnum hummocks. It was found that 3 cms. of peat had been deposited since the probes were inserted, eg. a probe originally positioned at -1 cms was at -4 cms.

A second shed was erected last November about 50 yards to the east of the original Grant hut. This larger model has made field work a much more comfortable experience.

f) Autecology of the genus Geum (K. Taylor, University College London).

A field experiment has been set up to assess the response of potted seedlings to climatic conditions at various altitudes during the winter of 1974-5. Seedlings were raised in a standard potting compost from seed collected in 1973 at Green Hole (Geum rivale) and near Helbeck Hall, Brough (Geum urbanum). Groups of twenty plants of each species have been placed in rabbit proof enclosures sited within an altitudinal range from 800 - 2,450 ft. Two of these sites are within the Reserve boundary at Rough Sike and Knock Fell, the other three are on the western escarpment at Helbeck.

g) Ecology and conservation potential of woodland in the northern Pennines.(R.A. Hynes, University College London).

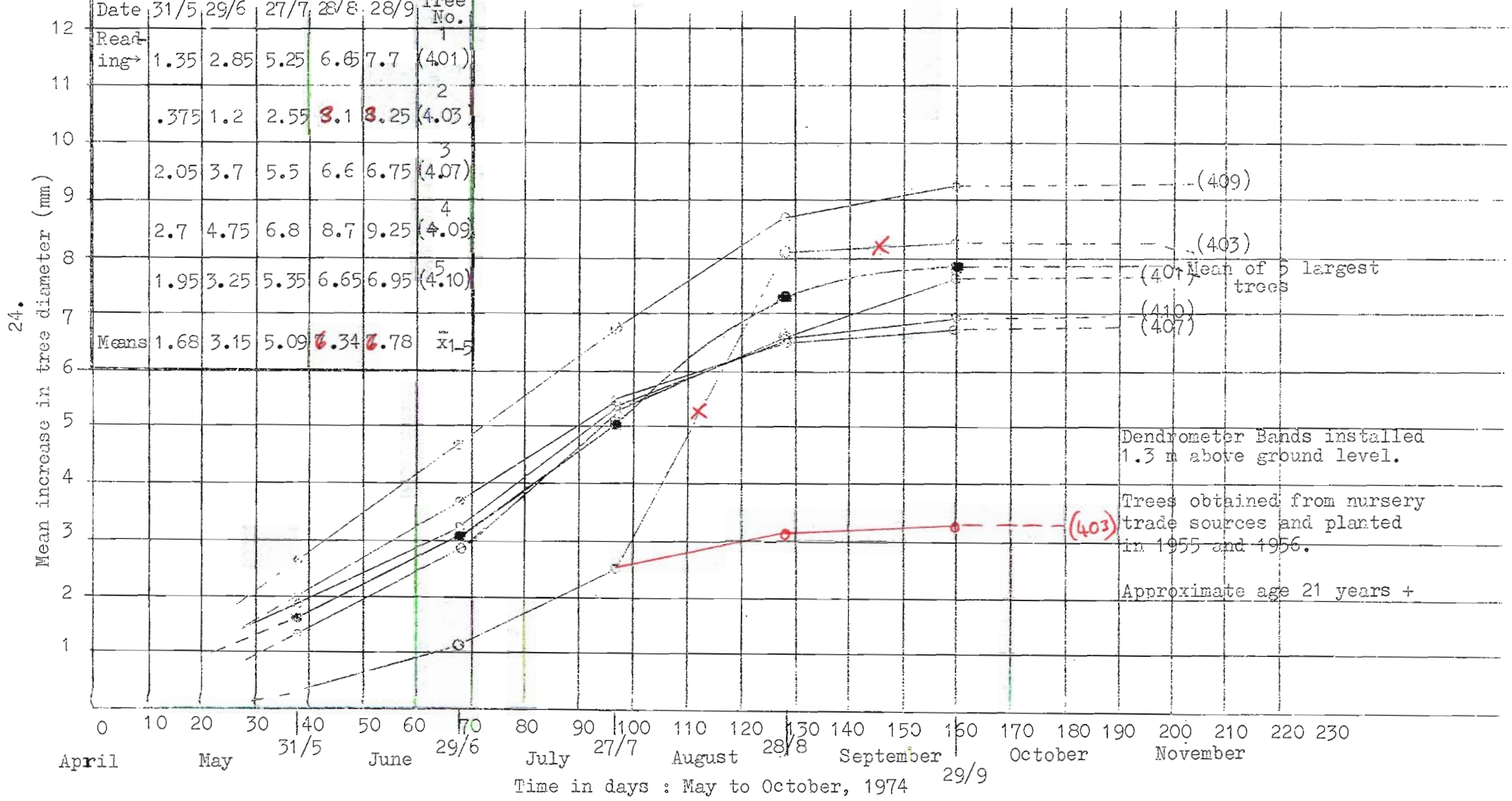
Within a study area that includes the high ground from Alston in the north to Middleton-in-Teesdale and Brough in the south, eighteen woodland sites have now been surveyed using a proforma previously outlined. A map survey of this area approaches completion.

Both radial and band dendrometers have been used to measure secondary increment. These measurements have been made at regular intervals on over 250 trees throughout the 1974 growing season. Five species are being studied: ash, birch, sycamore, wych elm and rowan. The main location is Helbeck Wood (near Brough) however rowan is also being studied at Swindale Beck and at Green Hole (1875 ft., 572 m O.D.). The Green Hole trees (rooted in mineral soil that overlies a shelf of carboniferous limestone) have grown particularly well this year. Fig 1 shows part of the mean diameter increment curves of five of the largest rowan in the enclosure.

Fig 1. Mean increase in diameter

Tree Nos. 401, 403, 407, 409, 410. Species - Sorbus aucuparia L. Location - Green Hole NY758328
Altitude - 1875 ft., 572 m O.D.

Date	31/5	29/6	27/7	28/8	28/9	Tree No.
Reading →	1.35	2.85	5.25	6.65	7.7	1 (401)
	.375	1.2	2.55	3.1	3.25	2 (403)
	2.05	3.7	5.5	6.6	6.75	3 (407)
	2.7	4.75	6.8	8.7	9.25	4 (409)
	1.95	3.25	5.35	6.65	6.95	5 (410)
Means	1.68	3.15	5.09	6.34	6.78	$\bar{x}_{1-5}$



Regular height and diameter measurements have been made on 300 birch and sycamore seedlings of Helbeck provenance, established on five sites over altitudinal range in the area. The exclosures are located at:-

1) Great Dun Fell (2,700 ft., 832 m O.D.),
2) Seavy Rigg (1,400 ft., 427 m O.D.),
3) Upper Level, Helbeck Wood (1,200 ft., 366 m O.D.),
4) Fox Tower, Helbeck Wood (1,000 ft., 305 m O.D.),
5) Lower Level, Helbeck Wood (800 ft., 244 m O.D.).

The seedlings (60 at each site) are set out in randomised Latin squares. Soil investigations have been made on all sites. These include tensiometer installations that have allowed a comparative assessment of soil moisture tensions across this altitudinal range.

Detailed studies have been made on 20 ecological sites within Helbeck Wood, ten of these being representative of the lower level and ten of the upper level of the wood. They are located on 20 of the stratified random points established for basal area-density studies in 1973. Investigations have included hemispherical photographs for a canopy cover analysis as well as leaf thickness and weight samples of upper and lower crown leaves.

The results of various studies are being closely linked to climatic data recorded at Great Dun Fell, Moor House and on Site 4 in Helbeck Wood (1,000 ft., 305 m O.D.).

At University College some 180 birch and sycamore seedlings (again of Helbeck provenance) are being used in growth cabinet experiments that largely parallel those set up in the field.

h) A physiological study of Sphagnum rubellum in relation to microclimate (D.M. Tattersfield, University of Leeds)

This season's studies have been made on the micro-environment around Sphagnum rubellum on blanket bog at Sike Hill, with particular reference to light intensity and carbon dioxide fluxes. Attempts have been made to measure the respiration of the bog surface, in order to evaluate the importance of upward carbon dioxide flux, under the Calluna canopy. The technique used, involving carbon dioxide absorption by alkali and subsequent titration, has given encouraging results but further replication is needed before any conclusions can be drawn.

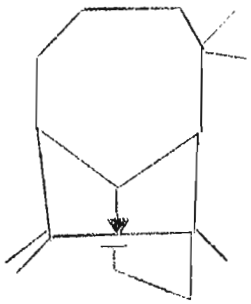
This preliminary work will provide a basis for measurements of photosynthesis under field conditions using the carbon -14 incorporation technique (see M. Ashmore 13th Annual Report, 1972) during the next growing season. The design and construction of a chamber suitable for enclosure of Sphagnum in situ on the bog surface is in progress, and the apparatus will be tested under laboratory conditions prior to field use.

i) Use of Scapania undulata in Biosynthetic studies (D.V. Banthorpe, University College London).

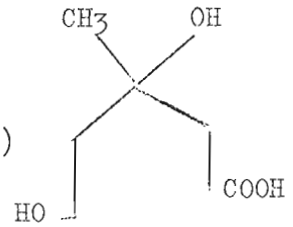
The terpene metabolism of liverworts seems to differ from that of most genera of higher plants in that large quantities of sesquiterpenes (C-15 compounds) are formed as secondary metabolites. In general, only small amounts of monoterpenes (C-10), diterpenes (C-20) and triterpenes (excluding steroids; C-30) occur. In particular, certain species of liverworts produce exotic sesquiterpenes that rarely crop up (and then in low percentage of the volatile oil) in higher plants.

We are interested in the biosynthesis and metabolism of longifolene (I) a sesquiterpene hydrocarbon, and its derivitives and our assays (glc; tlc; ms) of material produced by S. undulata reveal that (excluding steroids) longifolene is virtually the only terpenoid that accumulates and this to comprise ca 90% of an essential oil that occurs ca 0.5% w/w of the wet plant.

(I)



(II)



Thus we are using this as a source material for feeding studies using (2-^{14}C), (2R-^{3}H$_1$), (2S-^{3}H$_1$), (4R-^{3}H$_1$), (4S-^{3}H$_1$), (5-^{3}H$_2$) labelled mevalonic acid (II) - a known precursor of (I) to elucidate the route, mechanism and detailed stereochemistry of the biosynthesis of (I). We are also carrying out studies on soluble enzyme systems extracted from the liverwort in order to characterise further the steps involved.

j) Studies of periglacial phenomena (L. Tufnell, Huddersfield Polytechnic)

For the ninth consecutive year data were obtained on the movement of 5 ploughing blocks situated above 680 m on the Reserve. In general, displacements for the period August 1973 - August 1974 were slightly greater than those of the previous 12 months. A block in the upper Knock Ore Gill valley which was displaced 7.9 cm during the equivalent 1972-3 period continued its high rate of movement and experienced a shift of 7.6 cm between August 1973 and August 1974.

Work on selected block fields and screes from the Reserve and adjacent areas has been completed with the examination of a further 75 fragments at each of the two sites c. 190 m down valley from the radio station - Silverband Mine road junction. In all, over 1000 rock fragments have been closely studied in the Moor House region. The comparative aspect of this work has been continued with the examination of more fragments from limestone screes above Scout Scar, west of Kendal.

VI. RESEARCH BY OTHER ORGANISATIONS

a) Moth Survey (Dr. C.A. Edwards, Rothamsted Experimental Station).

The survey to correlate seasonal flight of noctuid moths and craneflies with climatic factors continues.

b) Two visits to Rough Sike, Moor House National Nature Reserve (Dr. N.L. Birkett, Kendal).

In 1962 Dr. D.T. Crisp carried out a trapping programme of insects in the small stream known as Rough Sike at Moor House. Some of the trapped Chironomidae (Diptera: Nematocera) he passed on to me for determination. Over the course of a number of years the material was identified as far as possible and some 32 species were definitely determined. Before writing up the results of this work I felt that I should visit the stream to gain some idea of the ecological environment and also perhaps make a few net catches by way of correlating with the trapped material. Unfortunately I was only able to visit Moor House on two occasions - 20 August and 3 September, 1972. On these two occasions I worked up and down the mere trickle of Rough Sike and netted such Chironomids as were flying as well as sweeping the marginal vegetation and under the overhanging banks. On these two visits I noted some 17 species of Chironomidae and of these only three were common to the trapped material! The days of my visit were both rather windy - a not uncommon occurrence at Moor House I gather - so it is more likely that many of the netted species were merely taking advantage of the gulley and banks of the stream for shelter having bred elsewhere on the Reserve.

Of the trapped material taken by Dr. Crisp one species proved new to Great Britain - Eudactylocladius obtexens Brundin, 1956. This was trapped between 4-12 October, 1962.

The full results of my work on the trapped material and netted material are currently in the press. In general terms the chironomids recorded are either of widespread general occurrence or species specialised to live in the acid-peaty type of environment provided on high moorlands of the north.

VII. INTERNATIONAL BIOLOGICAL PROGRAMME

The publication of the Springer-Verlag volume containing the Moor House IBP synthesis papers has been unfortunately delayed because of essential revision of some of the papers and delays in papers for other parts of the volume. Publication will now be in 1975.

A summary of the Moor House results was presented at the International Tundra Biome meeting in Abisko, Sweden in April. The meeting was attended by H.E. Jones, O.W. Heal (Merlewood), A.J. Holding (Edinburgh University), and J.B. Whittaker (Lancaster University) all of whom are involved in preparing synthesis papers for the final tundra volume to be published in the Cambridge University Press series on IBP.

a) Primary production (O.W. Heal, Merlewood)

The synthesis paper presented by H.E. Jones (A simulation approach to primary production, H.E. Jones and A.J.P. Gore) was concerned with a comparison of the rates of vascular plant production at a number of IBP Tundra sites. The comparison was made by means of a model, which required seasonal standing crop changes in the major plant compartments: green parts, wood, below-ground, standing dead etc. Initially it was intended to combine all vascular plants at each site, but as this totally obscured major differences in the behaviour of different species, the vegetation was subsequently treated as separate species. At Moor House, the two dominant vascular plants of the blanket bog were studied, Calluna vulgaris and Eriophorum vaginatum. The method involved deriving a set of simultaneous differential equations, one equation for each plant compartment, which showed all the gains and losses of that compartment. Transfer coefficients between compartments (eg. the fractional loss of green parts to standing dead) were derived from the estimated transfer as g $m^{-2}yr^{-1}$, divided by the mean biomass of the donor compartment. Seasonal variation in photosynthetic fixation was simulated by a negative cosine function fitted to the input to the green compartments. This input was called the throughput as it was derived from the sum of the outputs to the other compartments. By trial and error, values were assigned to the transfers between compartments and the equation set solved numerically to give weekly harvest values for all compartments throughout the year. These simulated values could be compared with the field data at the relevant harvest times, and if the values derived fell within $\pm$ standard error of the field data for all compartments, for all harvests the fit was judged to be significantly good. The derived input was therefore an estimate of the throughput in g $m^{-2}yr^{-1}$ for the particular species studied.

Results for the two Moor House species were throughput of 313 and 130 g $m^{-2}yr^{-1}$ for Calluna and E. vaginatum respectively. These values were lower than those obtained at some of the other less extreme tundra sites such as S. Georgia in Antarctica, where a highly productive sward of Acaena magellanica had an estimated throughput of 1345 g $m^{-2}yr^{-1}$. However they were similar to values obtained for a Deschampsia antarctica sward at Signy Island, Antarctica (385 g $m^{-2}yr^{-1}$), and for the components of the wet mire site at Hardangervidda, Norway (345 g $m^{-2}yr^{-1}$). As might be expected the climatically extreme tundra sites had considerably lower throughputs (90 g $m^{-2}yr^{-1}$ at Point Barrow, USA, wet meadows; 65 g $m^{-2}yr^{-1}$ in the Devon Island, Canada, sedge meadows and only 19 g $m^{-2}yr^{-1}$ on the beach ridges at Devon Island).

Gross differences in annual production between 'warmer' and 'colder' tundra sites were mainly due to variation in the length of the growing season, though this would not account for some differences such as those between Moor House and South Georgia.

The exercise was considered to be useful in that it applied a uniform technique to assessing production in a wide range of tundra sites. The advantage over more widely used methods to obtain production estimates (eg. subtracting minimum from maximum biomass), was that it showed up internal inconsistencies in the data and allowed a continuing reappraisal of the assumptions with incorporation of new data as it became available.

The proceedings of the Tundra Biome meeting on primary production and production processes (Dublin, April 1973) has now been published (Bliss and Wiegolaski, 1973). This contains 25 papers describing results from the various alpine, polar and bog sites which constitute the Tundra Biome. Because most of the results from primary production studies at Moor House were already published or in press, no detailed paper was presented. The volume provides much of the data base from which the international synthesis is being developed. (Copies of the volume can be obtained from O.W. Heal, ITE, Merlewood Research Station, Grange-over-Sands, Cumbria, LA11 6JU, Price £2.00).

Soil organisms and decomposition

Many of the results from microbiology and decomposition work at Moor House are included in the volume on "Soil organisms and decomposition in Tundra" (Holding et al 1974), where they are compared with results from other sites. The Tundra sites were classified, using principal component and cluster analyses, on the basis of their climatic and soil characteristics (French, 1974). The results (Fig 1) show the Moor House blanket bog and Juncus squarrosus sites to be associated with the bog sites in Ireland, at the extreme of a complex gradient from warm wet sites with soils of high organic and nitrogen content, to sites with cold dry mineral soils, low in nitrogen. The Moor House Festuca-Agrostis grassland (MHG) is isolated from the bog sites but is more closely associated with them than with the rest of the sites. This is one of a series of classifications used for comparison with microbial and decomposition characteristics.

a. Micro-organisms

The bacterial and fungal populations on the Moor House bog, based on dilution and direct counts respectively, are towards the high end of the range for Tundra sites. Correlations of populations with site characteristics showed that bacteria were positively related to the gradient from cold, dry, mineral, low nitrogen sites to warm, wet, organic, high nitrogen sites with a secondary trend related to pH, P and Ca (Holding et al 1974). Fungal mycelium length increased along a gradient reflecting increasing moisture content and organic matter, and decreasing pH, but unlike bacteria there was no marked relationship with P and K. (Dowding and Widden 1974).

Physiological tests on isolates of bacteria (Rosswall and Clarholm 1974) and fungi (Flanagan and Scarborough 1974) showed that the Moor House populations, in common with Tundra sites, have low potential for nitrification and denitrification, and high potential for sulphate reduction. The potential for cellulolysis, compared with other sites,

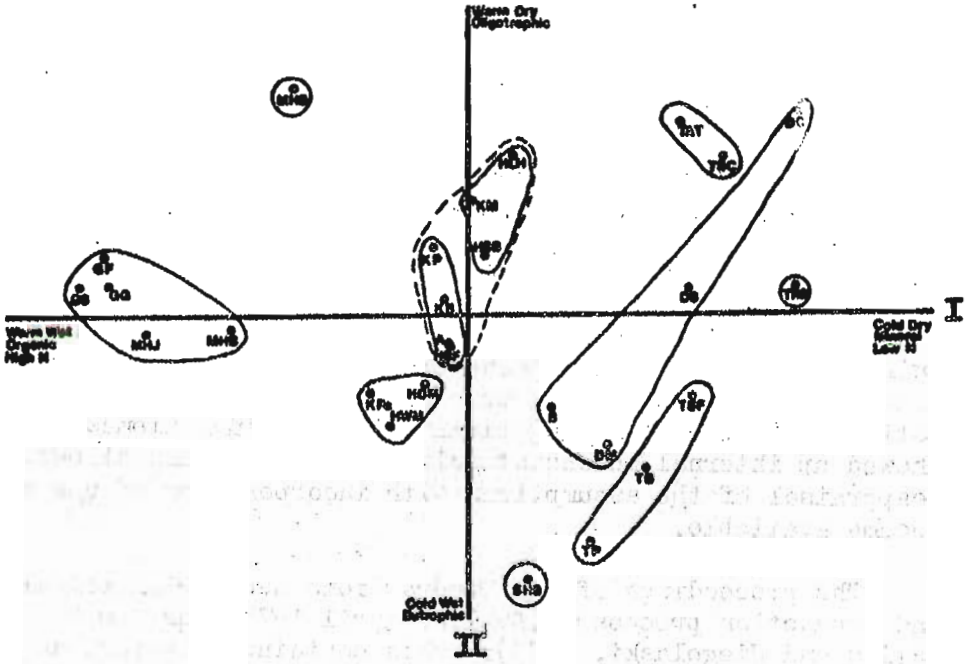


Figure 1. A classification of IBP Tundra Biome sites based on climate and soil data. Values for each site, derived from principal component analysis, are plotted along the first two component axes. First order clusters derived from cluster analysis are enclosed by solid lines, (French, 1974).

Site abbreviations:

MHB - Moor House blanket bog
MHJ - Moor House *Juncetum squarrosi*
MHG - Moor House *Agrosto-Festucetum*

Antarctica, Signy Island
SHB - moss bank

Canada, Devon Island
DM - wet meadow; DB - beach ridge; DC - crest of beach ridge

Finland, Kevo
KB - birch forest; KP pine forest; KM mountain dwarf shrub;
KPa - palsa

Ireland, Glenamoy
GB - bog; GG - grassland; GF - forest plantation

Norway, Hardangervidda
HWM - wet eutrophic meadow; HDM - dry eutrophic meadow;
HLH - lichen heath; HSB - snow bed; HBF - birch forest

Sweden, Abisko
A - mire

USA, Point Barrow
B - site 2 wet meadow

USSR, Taimyr, Tareya
TSC - spot crust, TSF - spot fissure; TRB - river bank;
TAT - *Astragalus-Dryas* tundra; TP - polygon centre; TB - polygon border.

was lower among fungi but higher among bacteria. The fungi were also low in gallic and humic acid degrading forms but amylolytic and pectinolytic types were common. As expected sulphate reducing bacteria were common in nearly all sites associated with waterlogged conditions, and there was a trend for cold-tolerance among the more extreme tundra sites - only 2% of the Moor House isolates produced colonies at 2°C compared with 84% at the alpine site in Norway. One surprising feature was the inability of bacterial isolates from the blanket bog to grow at pH 4.0, and only 1% grow at 5.0. It has been suggested that growth only occurs in micro-sites within the peat where the pH is relatively high. Another apparent anomaly is that although the estimated rates of nitrogen fixation are high compared with other sites the proportion of bacteria capable of growth on nitrogen-free medium was lower than in other sites. However the rates of N-fixation must be treated with caution because of the low number of samples involved (Alexander 1974).

b. Invertebrates

The relationship of the invertebrate fauna of Moor House to that at other bog and tundra sites is in the process of analysis. However, Whittaker (1974) examined data from a number of sites, to detect patterns of interaction between fauna and microflora. Comparison of field population changes in fauna and microflora indicated mite populations were negatively related to microbial population density and to rate of decomposition while enchytraeids appear to be positively correlated with microbial activity. Nematodes also show some correlation with bacterial numbers on a seasonal basis but there appears to be no correlation between Collembola and microbial counts. Experimental studies at Moor House and at Devon Island in Canada provide more detailed understanding of the interactions and show increased decomposition rates in the presence of enchytraeids and collembola. A preliminary analysis of soil fauna data from Point Barrow, Alaska by MacLean (1974), shows a negative relationship of fauna biomass to accumulated organic matter and a positive relationship between fauna biomass and primary production. The discussion on interaction mechanisms and responses is necessarily speculative and emphasises the need for experimental work designed to test some of the hypothesis derived from field observations.

c. Decomposition

Decomposition at Moor House is considered within a number of papers in the Fairbanks volume. Flanagan and Veum (1974) show that in a number of sites and substrates the rate of respiration is related to temperature with a Q_{10} of about 4, over the range of temperatures normally encountered in the field. A number of the studies show that microbial respiration continues down to about -7°C. Moisture, expressed as a % of the dry weight, generally retards decomposition below about 200% and above about 400%. Inhibition at high moisture is associated with development of anaerobic conditions but results from Moor House litters do not conform well with the general pattern, showing no marked inhibition of respiration at moisture levels in the region of 600%. There is no obvious explanation for this difference.

The rates of litter decomposition at Moor House, measured by weight loss, are at the higher end of the range observed in the Tundra Biome sites. This reflects the warm oceanic conditions relative to the true alpine and polar tundra. Using data from about 100 litters, from 21 sites in 10 countries, multiple regression analysis was used to

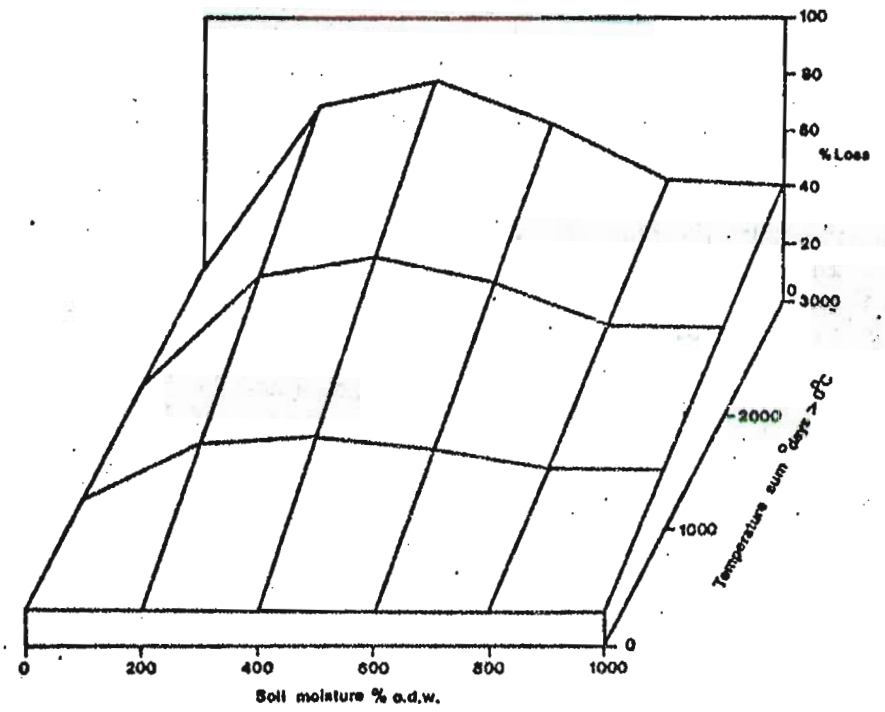


Figure 2. Regression surface for maximum first year % weight loss of litter in tundra sites, in relation to temperature sum and soil moisture. (Heal and French, 1974).

(Percent loss =

$11.62 + 0.0147 \times T \times W - 0.00289 \times T \times W^2 + 0.000152 \times T \times W^3$.

R = 0.769. Where T = sum of degree days for days when mean temperature at 5cm in soil is above $0^{\circ}C$, and W = $\frac{1}{2}$ (max+min) soil water expressed as % of dry weight.)

describe the relationship between weight loss in the first year and site temperature (sum of degree days above 0°C) and moisture (% dry weight) conditions. The regression surface (Figure 2) is based on maximum rates of weight loss for each site, Moor House blanket bog having a temperature sum of about 1900-2000°C and soil moisture of about 900% (Heal and French, 1974).

There is considerable within-site variation related to chemical and physical composition of different litters. An analysis, based on data from Moor House, Norway and USA showed negative correlations of weight loss against initial lignin concentration and C/N ratio. A positive curvilinear relationship of weight loss to initial % Ca and K was indicated but there was no clear correlation with N or P (Van Cleve 1974).

Variation resulting from substrate quality was removed by the use of two standard cellulose substrates, cotton strips (Heal et al 1974) and cellulose wood pulp sheets (Rosswall 1974). Weight loss from cellulose pulp at five bog sites at Moor House range from 14.5 ± 6.0 to 41.0 ± 6.9% in the first year. This is similar to the range observed for litters and is at the high end of the range for tundra sites. At the other extreme of the range are a series of 12 sites and subsites in the Taimyr Peninsula of USSR with annual losses of 0.5 ± 0.3 to 7.3 ± 0.9.

Losses in tensile strength of cotton strips inserted into the soil allow comparison of decay profiles as well as losses at the surface. A summary of results is given in Figure 3 where all losses were adjusted to a common time of 1 year. The Moor House sites (Syke Hill dry, Cottage Hill A + B and Bog Hill decomposition site) show relatively high rates at the surface but a sharp decline in rate with increasing depth. This type of profile was also found at the bog site in Ireland (Glenamoy) and in pools in the palsa site in Sweden (Abisko). It is associated with strongly anaerobic conditions resulting from waterlogging but a similar profile may result from dry conditions within the profile as indicated by the results from the lichen heath in Norway (Hardangervidd where a thin organic mat overlies dry sandy soil. A more gradual decline in depth was observed in a number of sites including palsa bogs. The remaining sites showed little change with depth or, in the case of one Antarctic site, an increase in rate with depth. Thus although the Moor House bog shows a high rate at the surface compared with typical tundra sites, the rate below about 10 cm is lower than in many tundra sites. In marked contrast with the bog, losses from cotton strips on the Festuca-Agrostis brown earth at Moor House are much higher and are off the scale shown in Figure 3. A multiple regression analysis of loss rates at the surface against site temperature and moisture conditions, showed a pattern similar to that for litters (Fig 2).

The results indicate that, in comparison with the alpine and polar tundra sites, the increases in microbial activity and decomposition expected from the relatively high temperatures at Moor House are constrained by the waterlogged, acid, low nutrient conditions on the bog. As a result the various measures of activity are only slightly above values for true tundra sites. In contrast, a reduction in water-logging and an increase in nutrient status - as shown in the Festuca-Agrostis grassland at Moor House and the managed grassland on peat at Glenamoy, Ireland, - is associated with an increase of almost an order of magnitude in the rates of decomposition and microbial activity.

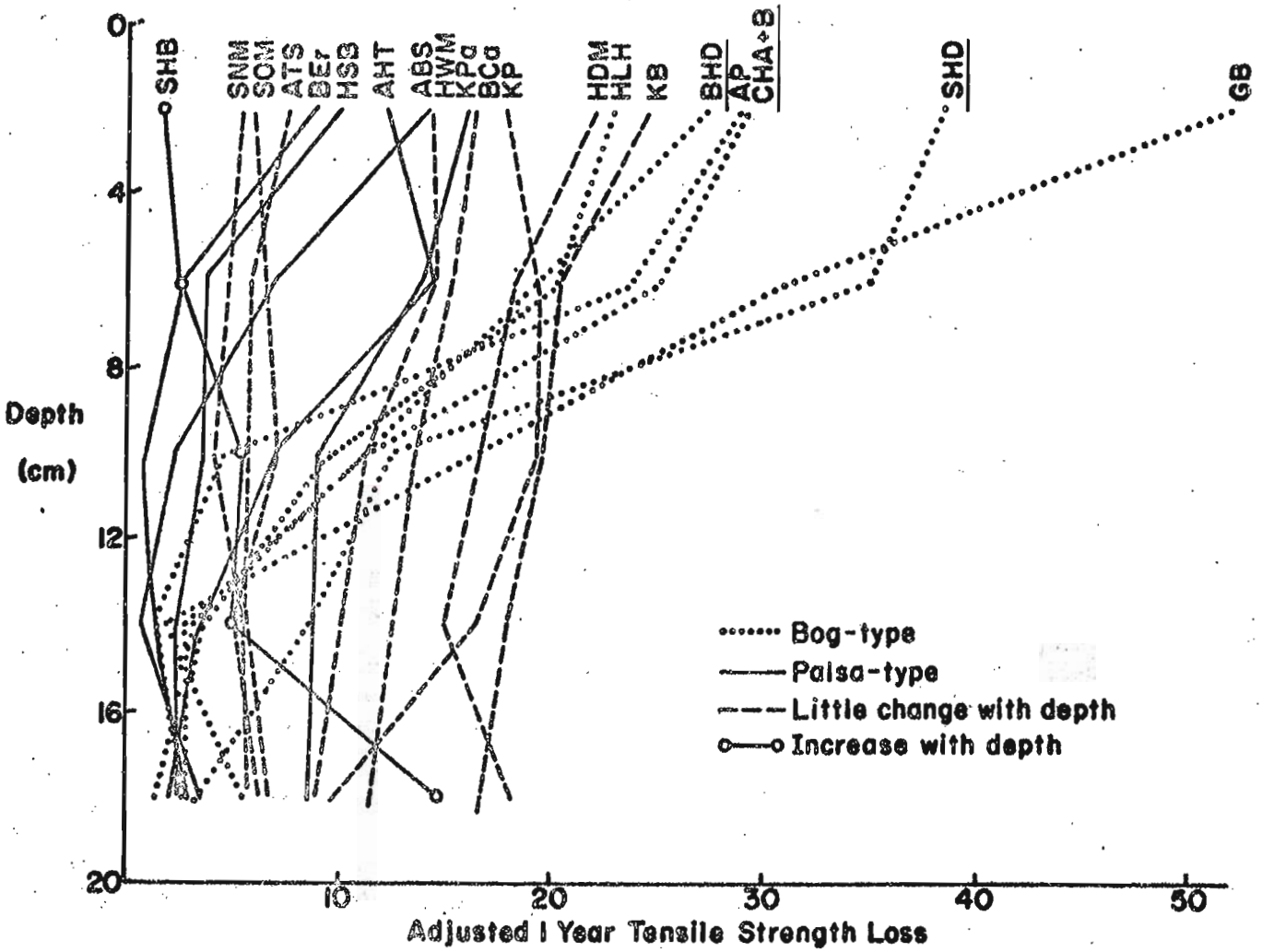


Figure 3. Profiles of loss in tensile strength after 1 year for a range of tundra sites. (Heal, Howson, French and Jeffers, 1974).

Site abbreviations:

Moor House
BHD - Bog Hill (decomposition site); CHA+B - Cottage Hill (average A+B sites)
SHD - Syke Hill (dry site)

Antarctica, Signy Island
SHB - moss bank; SOM - old moraine; SNM - new moraine

Finland, Kevo
KB - birch forest; KP pine forest; KPa - palsa

Ireland, Glenamoy
GB - bog

Norway, Hardangervidda
HWM - wet eutrophic meadow; HDM - dry eutrophic meadow; HLH - lichen heath; HSB - snow bed

Sweden, Abisko
AHT - hummock top; ATS - top of hummock slope; ABS - bottom of hummock slope; AP - pool

USA, Point Barrow
BEr - *Eriophorum* sward; BCa - *Carex* sward

The decomposition studies have included a combination of a) experimental studies in which relationships between process rates and environmental factors such as temperature and moisture were defined and b) measurement of rates of decomposition in the field. The former have been used to construct a generalised model (ABISKO) of decomposition processes. From this simulation, rates of decomposition can be calculated on the basis of environmental data and the estimates evaluated against observed field rates. The general model, described in Bunnell and Dowding (1974), is designed to compare decomposition processes in the various Tundra sites. It thus provides a formalized description of the mechanisms involved in decomposition at Moor House. An evaluation of the model is nearing completion and will be published in the Tundra synthesis volume in the CUP series.

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*HEAL, O.W. & FRENCH, D.D. Decomposition of organic matter in tundra. In Holding et al.

* HEAL, O.W., HOWSON, G., FRENCH, D.D. & JEFFERS, J.N.R. Decomposition of cotton strips in tundra. In Holding et al.

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* Papers directly involving UK IBP personnel.

APPENDICES

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Staff List

Officer-in-Charge	M. Rawes
Scientific Staff	R. Williams
	R.B. Marsh
	Miss L.M. Teasdale
Warden	J. Parkin
Estate Worker	P.J. Holms
Housekeeper	Mrs. G.G. Dunn (April - October)
Part-time Warden	J. Rose (November - March)
Honorary Wardens	B.J. McArthur
	J. Hollington
	O.W. Harrison
F.B.A. Staff	Dr. D.T. Crisp
	Dr. P.D. Armitage
	P. Cubby

Meteorological Summary for Moor House 1973 (Met. Office Station No. 7188)
c. 558 m O.D. (Main Instrument Site) Lat. 54° 41' N., Long 2° 23' W. Nat. Grid Ref. NY/758328

	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Mean maximum temperature °C	3.2	2.6	5.9	5.4	10.6	14.6	15.0	15.3	12.3	8.3	4.4	3.2	8.4
Mean minimum temperature °C	-1.4	-2.9	0.7	-1.4	3.0	6.8	7.4	7.4	6.5	2.4	-1.1	-2.2	2.1
½ (max. + min.) temperature °C	0.9	-0.1	2.6	2.0	6.8	10.7	11.2	11.3	9.4	5.3	1.7	0.5	5.2
Highest maximum temperature °C	8.0	9.6	11.7	12.9	19.0	19.4	19.3	23.0	19.6	18.1	12.1	7.6	23.0
Lowest minimum temperature °C	-11.0	-15.8	-6.6	-9.6	-3.2	-1.1	0.6	2.5	-1.7	-4.9	-9.3	-14.0	-15.8
Lowest maximum temperature °C	-3.5	-3.0	1.1	0.2	5.0	8.9	11.4	9.2	7.0	1.6	-4.0	-1.5	-4.0
Highest minimum temperature °C	3.9	3.7	3.1	3.3	10.8	11.5	12.0	10.7	12.8	8.5	7.0	4.5	12.8
Lowest grass min. temp. °C	-12.0	-15.6	-12.9	-14.5	-9.4	-12.4	-4.3	-2.5	-6.5	-10.6	-13.5	-18.1	-18.1
Av. earth temperature at 30 cm - 0900 GMT - °C	2.0	2.3	2.7	3.4	6.2	10.1	11.8	12.1	10.9	7.2	4.7	2.3	6.3
Rainfall mm	123	129	74	121	131	65	112	179	83	119	116	233	1485
Greatest daily rainfall mm	28	24	11	15	34	11	27	43	23	42	24	52	52
No. rain days	19	25	14	21	19	10	17	19	18	18	18	24	222
No. wet days	15	19	13	17	14	14	15	15	11	12	14	21	180
Days snow/sleet falling	9	10	7	11	3	0	0	0	0	4	10	15	69
Days with snow lying 0900GMT	14	18	6	8	0	0	0	0	0	0	2	13	61
Days with hail	1	3	5	6	4	1	0	2	2	2	1	0	27
Days with snow/ice pellets	3	2	1	7	0	0	0	0	0	1	1	3	18
Days when thunder heard	0	0	0	0	2	0	0	1	0	0	0	0	3
Days with fog at 0900GMT	9	7	5	2	1	2	5	2	3	3	2	8	49
Days with air frost	19	16	20	21	8	1	0	0	1	8	17	21	132
Days with ground frost	27	22	24	25	13	5	6	1	5	15	26	27	196
Av. daily bright sunshine hrs	1.25	2.66	4.11	3.90	4.93	5.51	4.85	5.14	3.16	2.05	2.50	0.80	3.41
Total sunshine hours	38.8	74.4	127.4	117.1	152.8	165.4	150.3	159.3	94.9	63.5	74.9	24.7	1243.5
Total snow fallen cm	87	87	16	38	0	0	0	0	0	0	3	25	256
Greatest depth snow lying cm	74	13	11	15	0	0	0	0	0	0	3	20	74
Days with gale (anem. record)	0	3	2	0	1	2	1	1	0	0	4	6	20
Potential evaporation mm	-	-	(63)	(81)	84	79	77	75	45	30	(19)	-	(441)(Apr-Sep)
Potential water deficit mm	-	-	-	14	14	59	30	33	16	10	0	-	166
Potential water surplus mm	-	-	-	54	61	45	65	137	56	99	97	-	(418)

Meteorological Summary for Great Dun Fell 1973
c. 655 m O.D. Lat 54° 35'. Long 02° 28' W. National Grid Ref. NY/710322

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Days with snow lying	11	18	7	16	2	0	0	0	0	0	7	-	-
Fog at 0900 GMT	25	15	14	14	13	14	10	18	18	(18)	15	-	-
Wind Speed - knots	21.3	24.2	21.0	21.7	20.5	18.4	15.6	18.1	18.5	20.1	25.3	27.3	21.0
Sunshine hours (daily mean)	1.30	1.61	3.17	2.85	3.33	-	-	-	-	-	-	-	-
Days with sleet or snow at 0900 GMT	12	15	12	20	5	1	0	0	0	(5)	10	-	-
Days with hail	0	0	1	1	1	0	0	0	0	0	0	-	-
Days with ice	0	0	1	1	0	0	0	0	1	0	0	-	-